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Utilization of Proteins by the Growing Chick

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The nutrient group known as the proteins has commanded the attention of nutrition investigators for many years. The word *protein* is very appropriately derived from a Greek word meaning "of the first importance." Without belittling the importance of carbohydrates, fats, minerals, and the more recently discovered vitamins, it may be stated that efficient utilization of our protein resources constitutes one of our most important economic problems.

Proteins are essential constituents of both plant and animal cells. Proteins from different sources are not identical substances, but may differ widely in their basic chemical structure. A point of similarity is that they all contain nitrogen, carbon, hydrogen, and oxygen.

THE THEORY OF PROTEIN UTILIZATION

A difference in the nutritive value of proteins from different sources has been observed and reported by many investigators. Although much of the early protein research work must be questioned because it was done before present information on vitamin, radiant-energy, and inorganic requirements had been obtained, the conclusion that great differences in nutritive values of different proteins exist is clearly valid.

The most generally accepted theory of protein metabolism is that certain combinations of the cleavage products of protein digestion are essential for the nutrition of the animal cell. These cleavage products are known as amino acids and nineteen of them have been definitely identified at this time. The recognized amino acids are glycine, alanine, serine, valine, leucine, isoleucine, aspartic acid, glutamic acid, hydroxyglutamic acid, arginine, lysine, cystine, methionine, phenylalanine, tyrosine, trytophane, histidine, proline, and oxyproline. These are the building stones of the protein molecule, which is indeed very complex, so complex, in fact, that physical chemists are only able to estimate the probable molecular weight of even the simplest of the proteins.

German chemists have applied the name "Bausteine," building stones, to these cleavage products. This is really a happy choice, because the analogy of building animal tissue and building a dwelling is an excellent one. It is as if a house were torn down and another is to be erected from the salvaged material. If the second house is entirely unlike the first in structure, there will be many pieces to discard and the new house will be smaller than the original. This in principle is what happens when food proteins are converted into body proteins in animal metabolism.

This illustration shows with essential accuracy the most commonly accepted theory of protein metabolism. The student of nutrition will recognize that it furnishes only a rough outline, the full details of which await many years of painstaking research work.[1]

THE BASAL RATION

In considering the problem of protein utilization, an endless number of perplexing questions arise. One must of necessity take one situation, or, as the civil engineer might term it, one "bench mark" from which to start operations. For the experiments herein reported it was decided to study protein utilization at a certain level of intake. As a basal ration two products most commonly used in practical poultry rations were taken.

The basic poultry feedstuffs in the United States are corn and the by-products of wheat milling. Our annual corn production in the United States averages about 3,000,000,000 bushels, 80 per cent of which is used for animal production. Corn is palatable and easily available in most communities. Corn prices markedly influence the value of other feedstuffs which may be used in poultry rations. Economically corn is, and probably will be for many years, the most important constituent of poultry rations.

Next in importance as basic feedstuffs are the milling by-products of wheat. About 6,000,000 tons of these by-products are available for animal feeding each year. Because of this liberal supply, standard wheat shorts were included in the basal ration for the series of experiments herein reported.

The basal ration for the first five series of experiments was composed of—

Yellow cornmeal	50.0
Wheat shorts (brown)	25.0
Protein concentrate (adjusted to 32% protein level)	18.0
Feed yeast	3.0
Cod liver oil	1.0
Salt mixture No. 311[2]	3.0
	100.0

[1] For more detailed information on the biochemistry of the amino acids, the reader is referred to the very comprehensive discussion by H. H. Mitchell and T. S. Hamilton published by the Chemical Catalog Co., 419 Fourth Ave., New York.

[2] Salt mixture No. 311 is composed of 60 parts raw bone meal, 20 parts calcium carbonate, and 20 parts common salt.

This basal ration is complete for recognized vitamins and minerals, and, when the protein concentrate used is of good quality, results in an excellent growth rate. In addition to the cod-liver oil included in the ration the chicks used for these experiments had free access to direct sunshine. The feed yeast was included in the basal ration to insure a sufficient supply of the vitamin B complex. Later experimental work indicated that this basal ration was sufficient at least for the B-1 or antineuritic factor without the yeast, but since the yeast had been included in the first series of experiments, it was included in all rations at the same level.

The protein level of the complete ration as offered all lots in these experiments was 16.51 per cent. This protein was distributed as follows: corn 30.28 per cent of the total, wheat shorts 25.74 per cent, feed yeast 9.09 per cent, protein concentrate 34.89 per cent.

IMPORTANT PROTEIN CONCENTRATES

A group of ten products was selected after a preliminary survey of the protein concentrates now readily available on the market. The approximate annual production of these at the present time is given in Table 1.

TABLE 1.—*Production of protein concentrates in the United States (estimates obtained chiefly from the U. S. Department of Agriculture and Commerce)*

Product	Approximate annual production	Product	Approximate annual production
	Tons		*Tons*
Meat meal, tankage, and meat scraps	300,000	Corn gluten feed	450,000
Blood meal	50,000	Corn gluten meal	40,000
Fish meal	80,000	Soybean meal	70,000
Linseed oil meal	750,000	Dried buttermilk	22,000
Cottonseed meal	2,300,000	Dried skim milk	70,000

Relative prices and biological values of these when used by themselves and in combinations are factors which will determine which products can be used most economically. The relative costs per unit of protein can, of course, be determined very readily, but information about the biological value, which is of even greater importance, is made available only through experimental work.

The products listed (see Table 2) are not of course perfectly standardized as to chemical composition. Care was exercised, however, to select representative samples for the experimental work so that the materials used represent the products named

TABLE 2.—*Average composition of protein concentrates* [1]

Kind of Feed	Composition						
	Moisture	Protein (average)	Range of protein	Fat	Nitrogen free Extract	Ash	Fiber
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Meat scraps	8.8	53.8	33—60	11.2	3.8	23.4	2.1
Blood meal	9.8	81.6	79—83	1.0	3.5	3.2	....
Fish meal	9.5	60.8	48—65	8.0	.....	15.2	....
Linseed oil meal (O. P.)	9.2	33.6	30—37	7.6	35.2	9.2	7.9
Linseed oil meal (N. P.)	9.7	37.2	35—40	2.8	36.2	9.7	8.6
Cottonseed meal	7.8	38.6	35—45	6.6	30.2	6.5	10.3
Corn gluten feed	8.9	24.9	23—25	3.7	52.8	2.2	7.0
Corn gluten meal	9.0	35.4	34—42	4.5	48.2	1.4	2.0
Soybean meal	10.4	41.1	40—47	7.2	29.0	5.1	4.3
Dried buttermilk	11.3	31.2	29—36	6.1	15.8	9.1	....
Dried skim milk	7.4	37.3	32—38	1.0	46.3	8.0	....

[1]Compiled from analyses reported by State Feed Control Laboratories, Agricultural Experiment Stations and U. S. Department of Agriculture.

as fairly as is possible under the present condition of non-standardized manufacturing policy. Since the original concentrates varied in their protein level, those containing more than 32 per cent of protein were mixed with finely pulverized cornstarch to bring them all to the standard level of 32 per cent. Eighteen units of the adjusted protein concentrate were then added to 82 units of the basal ration as listed to make the complete diet for the lot. This permitted a comparison of the value of these concentrates at exactly the same level of protein intake, when used in conjunction with the corn and wheat products as included in the basal ration. The biological value of these proteins may admittedly be somewhat different when used in conjunction with other feedstuffs, but it is believed that the basal ration used includes the products which for many years will be the basis of poultry rations.

DESCRIPTION OF PROTEIN CONCENTRATES

MEAT AND BONE MEAL

About 300,000 tons of meat meal, meat scraps, tankage, and meat and bone meal are available annually as by-products of the meat-packing industry.

The Association of Feed Control Officials of the United States has adopted the following tentative definitions for the product which was used in the experimental work herein reported.[3] "**Meat Scraps** are the ground, dry-rendered residue from animal tissues exclusive of hoof, horn, manure and

[3] *Definitions of Feeding Stuffs,* Association of Feed Control Officials of the United States, 1927.

stomach contents. When this product contains more bone than an amount equivalent to 22 per cent of tricalcium phosphate, $Ca_3(PO_4)_2$, it shall be designated as meat and bone scraps." A product meeting these requirements is also sold as meat and bone meal.

The raw materials available for meat-packing by-products vary considerably, so that some variation in their nutritive value is to be expected. Hoagland and Snider (4, 5) have shown that the proteins of different animal tissues and of different species have different nutritive values for growing rats.

Work with chicks by Prange, Carrick, and Hauge (6) prompted the conclusion that "meat scraps from various manufacturers did not give the same rate of growth when fed at the same protein level." The same investigators (7) observed that tankages obtained from two different manufacturers gave unsatisfactory results in chick rations when fed at levels of 15 per cent. They suggest that, since considerable dried blood is used in the manufacture of some tankages, the reduced palatability from such additions may account for the poor results with this concentrate.

BLOOD MEAL

About 50,000 tons of blood meal are produced in the United States annually. This product is made of ground, dried blood. In the process of manufacture the blood is coagulated or cooked by means of live steam in large steam tanks. The moisture content is reduced in a hydraulic press and a steam dryer at high temperatures. The product is then ground and sacked for distribution. Its chemical composition shows it to be very high in protein, but the biological value of the protein is apparently much lower than that of other animal by-products. Hoagland and Snider (8) report very unsatisfactory results from the use of dried blood in rat rations because of low palatability.

FISH MEAL

About 80,000 tons of fish meal are produced in the United States each year. An average fish meal will contain from 60 to 65 per cent protein and 15 per cent ash, chiefly tricalcium phosphate.

The method and the equipment used in making fish meal resemble those used in making packing-house by-products. The raw material is steam cooked, pressed, dried, and ground into a fine meal. At the present time about half of the fish meal available is prepared from menhaden fish. The menhaden belongs to the herring family. It is not used for human food, and the entire fish is used for making meal. Because of its outstanding importance in this group of protein concentrates, menhaden meal was used in these experiments.

LINSEED OIL MEAL

About 750,000 tons of linseed oil meal are obtained each year as a by-product of the extraction of linseed oil from flaxseed. Flaxseed contains on the average about 34 per cent of oil. About 90 per cent of this can be extracted by the methods most commonly used, leaving a residue which when finely ground is known as old-process linseed oil meal. This product averages about 34 per cent protein.

Very little research work has been reported on the value of linseed oil meal in chick rations. Bethke and associates (10) report a comparison of cottonseed meal and linseed meal in chick rations with the advantage decidedly in favor of cottonseed meal.

COTTONSEED MEAL

About 5,000,000 tons of cotton seeds are produced each year as a by-product of cotton production. Approximately thirty-eight gallons of oil and 800 pounds of meal are obtained from a ton of cotton seeds. The total production of meal, therefore, is about 2,300,000 tons each year, fluctuating slightly as cotton production fluctuates.

In the process of manufacture the cotton seeds coming from the gins are put through a machine known as the huller. The huller cuts the seeds so that the kernels drop out when the cut seeds are put through a machine known as a beater. The hulls and kernels are then put through shakers, next between rollers, and then into the cooker where they are cooked by steam under 30 to 100 pounds of pressure for about 40 minutes. The cooked product is subjected to pressure and a hard slab cottonseed cake is obtained. This is crushed or ground into the desired degree of fineness.

The Association of Feed Control Officials has adopted the following definition for Cottonseed Meal, Prime Quality.

"Cottonseed Meal, Prime Quality, must be finely ground, not necessarily bolted, of sweet odor, reasonably bright in color, yellowish, not brown or reddish, free from excessive lint, and shall contain not less than 36 per cent of protein. It shall be designated and sold according to its protein content. Cottonseed meal with 36 per cent of protein shall be termed '36 per cent Protein Cottonseed Meal, Prime Quality.' Higher grades shall be similarly designated as, for example, '43 per cent Protein Cottonseed Meal,' etc."

The 36 per cent protein requirement is evidently easily attained, since the 872 samples of cottonseed meal included in a table in Bulletin No. 189 of the Texas Agricultural Experiment Station (11) averaged 40.37 per cent protein.

Hartwell and Lichtenthaeler (9) in one of the earliest experiments on protein utilization for which chicks were used, reported fairly good growth on cottonseed meal when mineral supplements were used. Beef scrap at the same protein level, however, produced a better growth rate. Bethke *et al* (10) compared cottonseed meal and linseed meal proteins for growing chicks and results definitely favored the cottonseed meal.

CORN GLUTEN FEED AND GLUTEN MEAL

Millions of bushels of corn are used each year in the manufacture of cornstarch, corn syrup, and other corn products. Several by-products are obtained, the most important of which are corn gluten feed and corn gluten meal.

In the manufacture of starch and syrup the corn is steeped in water containing a small amount of sulfurous acid and is then passed through a mill which breaks up the kernel so that the germ will separate. The partly processed product is next soaked in salt water, and the starch, together with those parts of the kernel containing the least fat, sink to the bottom of the vat. The germ, which is lighter than the other parts because of its higher fat content, floats in the steep water and is removed. Some of the oil is removed from this latter product and the residue is made into what is known as corn oil cake meal, a product containing about 18 per cent protein and 8 per cent fat.

The gluten and starch are still mixed as the product comes through the second process. Starch is heavier than gluten and by the use of large quantities of water and special shaking machines the starch and gluten are separated. The gluten is put through filter presses to rid it of most of the water, and from there goes to the driers where its moisture content is reduced to about 10 per cent.

Corn gluten feed contains from 23 to 25 per cent of protein, while corn gluten meal averages about 40 per cent.

SOYBEAN MEAL

During recent years soybeans have been used quite extensively for the production of oils for soap making and paint mixing. About 32 gallons of oil and 1,600 pounds of cake by-product are obtained from a ton of soybean seeds. It is the cake, pulverized into convenient size, that is used for livestock and poultry feeding. The methods of extracting the oil from the seeds are essentially the same as are employed in extracting linseed oil and cottonseed oil.

Kaupp (12) recommends soybean meal in chick rations, but no data are presented from which one can compare the nutritive value of soybean proteins with other concentrates. Card (13) found that soybean oil meal could be used to replace meat scraps and that the chicks fed soybean oil meal were in every way as good as those given meat scraps, provided there was no other limiting factor.

Kennard and associates (14) report finding soybean meal a better supplement to cornmeal than meat scraps. They emphasize the need of mineral additions when soybean meal is used as the source of supplemental protein. Phillips, Carr, and Kennard (15) also report better growth from soybean meal additions to a yellow corn base than was obtained from meat scrap additions at a comparable level. Combinations of meat scraps and soybean meal were not as efficient as the soybean meal alone.

DRIED BUTTERMILK

Large quantities of buttermilk are available each year as a by-product of the manufacture of butter. This by-product carries most of the protein, ash, and milk sugar contained in the cream before churning. Buttermilk, as it comes from the churn, contains about 90 per cent water and is consequently too bulky a product to be transported freely. Equipment has been developed for removing most of the moisture, resulting in a flaky powder which is widely used in poultry rations. There are several different methods of manufacturing dried buttermilk, the most commonly used being the vacuum drum method. Whether there is a difference in the nutritive value of dried buttermilk made by different processes has not yet been determined. About 22,000 tons of dried buttermilk are produced in the United States annually.

Dried buttermilk proteins are relatively expensive, but the milk proteins enjoy such an excellent prestige that the larger part of our annual dried buttermilk production is used in poultry rations. Satisfying research work which can be used as a basis for properly evaluating this product is unfortunately lacking.

DRIED SKIM MILK

About 70,000 tons of dried skim milk are produced annually in the United States at the present time. Dried skim milk differs from dried buttermilk in that it contains more protein, more sugar, less ash, and less lactic acid. Whether the protein in dried skim milk is biologically as useful as that of dried buttermilk is probably the most important question involved in the use of these feedstuffs.

EXPERIMENTAL METHODS

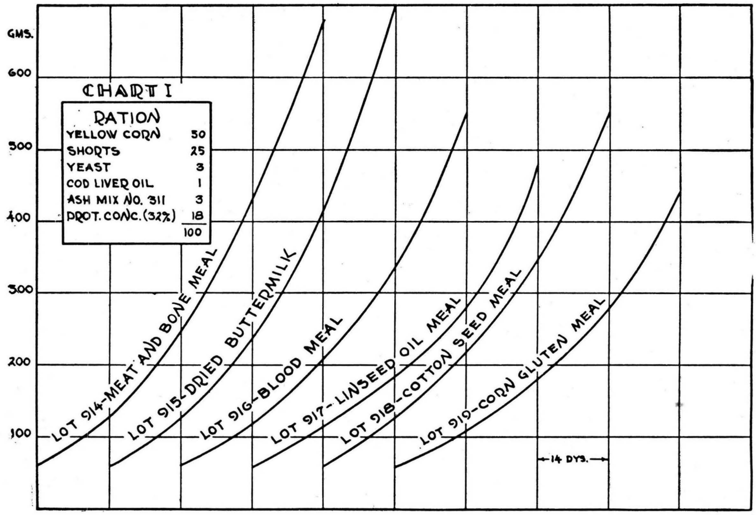
The chicks used for the experiments were produced from the University breeding flocks. They were brooded carefully for seven days and were then selected for vigor and normality for the experimental units. The chicks were individually banded. They were weighed individually at the beginning of the experiment, at the end of four weeks, and again at eight weeks.

A difference in the growth rate of sexes is observed early in chicks, so that an unequal distribution of the sexes would introduce an error if the mean weight of the group were taken as the measure of the nutritional value of the ration. Accurate sex determinations can be made at nine weeks, and this was done. It was observed (1) that the factor 1.14 could be used to translate female weights at nine weeks into male equivalents. The mean weight of the group, with the correction factor applied as indicated, was then taken to represent the relative nutritive value of the ration which the lot received.

The concentrates used for these studies differed in the quality and quantity of ash as well as of protein content. The potential alkalinity and acidity of the rations used were not the same for all rations, but earlier investigational work by Mussehl, Hill, Blish, and Ackerson (2) indicated that growing chicks were able to adjust themselves to rather wide variations in this factor. The inclusion of cod liver oil in the basal ration and provision for direct sunlight radiation assured optimum conditions for calcium and phosphorus assimilation and fixation. The calcium-phosphorus ratio of the rations used also varied somewhat according to the concentrate used, but earlier observations (2) indicate that the growing chick can adjust itself to a considerable range in this factor also when liberal amounts of vitamin D and direct sunshine are provided.

In the first series of experiments the nutritive values of commercial meat and bone meal, dried buttermilk, blood meal, linseed oil meal, cottonseed meal, and corn gluten meal were compared. Thirty heavy-breed chicks were used for each lot. Probable error calculations were made for the last weights after female weights had been corrected to the male equivalent by the factor 1.14. These data are given in Table 3.

The results of a statistical study of the final weights of the chicks used for this experiment are given in Table 8. Meat and bone meal is in all cases used as the standard with which the other concentrates are compared.

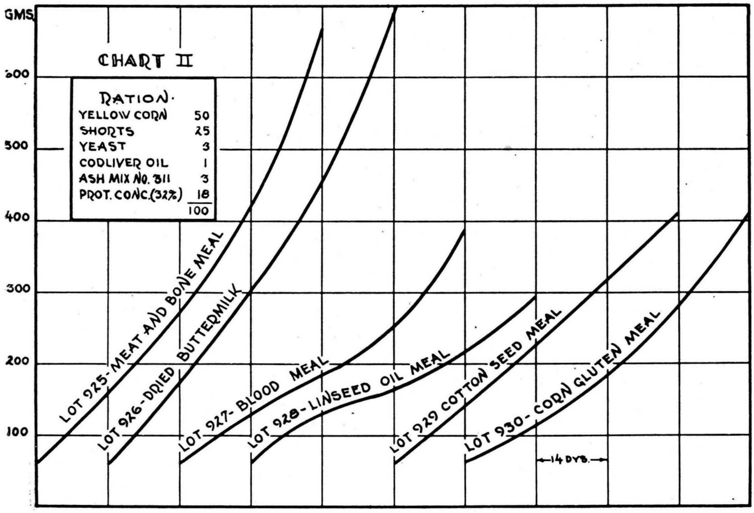


The second series of experiments was a repetition of the first series. Table 4 presents the detailed data of this series.

From the results of the first two series of experiments it is evident that there are great differences in the utilization of the various protein concentrates when used to supplement our basal ration. One is hardly justified in concluding that all animal protein concentrates have a biological value superior to that of plant-derived concentrates. A comparison of the growth-producing value of meat and bone meal, dried buttermilk, and blood meal shows that for some reason not yet evident the blood-meal proteins are not efficiently utilized by the growing chick. The fact that this difference was observed

TABLE 3.—*First series—30 chicks per lot*

Lot No.	Protein Concentrate	Weights: Initial	Weights: 28 days	Weights: 56 days	Deaths
		Gms.	*Gms.*	*Gms.*	*No.*
914	Meat and bone meal	59	252	680 ±17.5	1
915	Dried buttermilk	59	238	701 ±21.7	2
916	Blood meal	59	210	553 ±10.8	0
917	Linseed oil meal (O. P.)	59	185	476 ±11.0	1
918	Cottonseed meal	59	224	545 ±16.1	1
919	Corn gluten meal	59	181	441 ±10.3	1

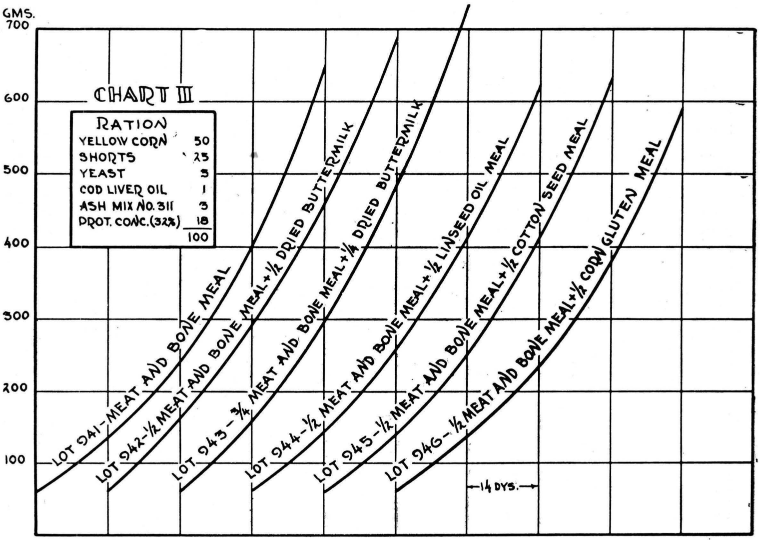


even at the time of the first weighing after the chicks had been on the experimental rations only two weeks suggests that the palatability factor may be a partial explanation. A difference in the palatability of the various rations was noted but no attempt was made in this series of experiments to control the feed intake at the same level for all lots. This phase of the project still remains to be done.

The generally accepted theory of protein utilization has already been referred to in the earlier part of this bulletin. Reasoning from this theory, we would expect a more efficient utilization when protein is provided through several products rated to be of equal or nearly equal value. For the third

TABLE 4.—*Second series—27 chicks per lot*

Lot No.	Protein Concentrate	Weights			Deaths
		Initial	28 days	56 days	
		Gms.	*Gms.*	*Gms.*	*No.*
925	Meat and bone meal	60	252	674 ±23	3
926	Dried buttermilk	60	303	693 ±14.4	1
927	Blood meal	60	180	383 ±12.7	0
928	Linseed oil meal (O. P.)	60	164	297 ±12.4	1
929	Cottonseed meal	60	227	414 ±12.5	1
930	Corn gluten meal	60	185	410 ±13.6	2



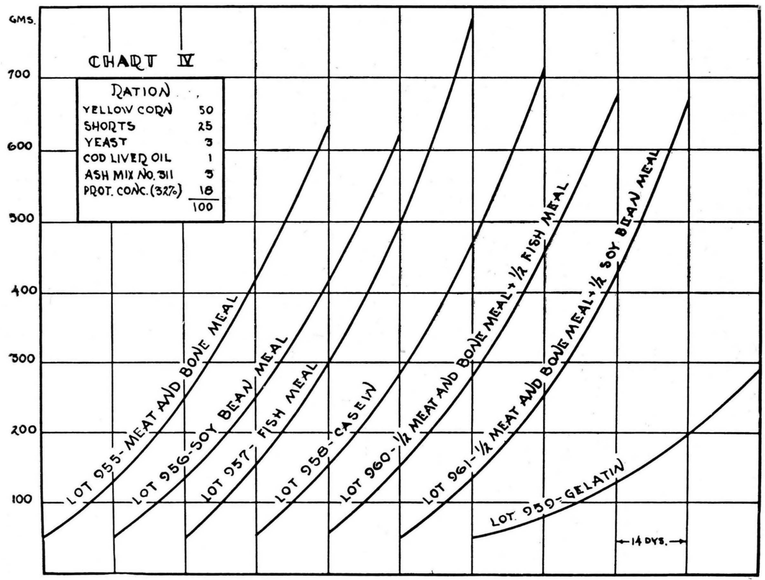
series of experiments, therefore, we made protein concentrates by combining two products so that half of the protein in the concentrate was from one product and half from another. Eighteen pounds of a protein concentrate adjusted to a 32 per cent level contains 5.76 pounds of protein. The concentrate for Lot 942, for instance, was therefore adjusted to carry 2.88 pounds of meat and bone meal proteins and 2.88 pounds of dried buttermilk proteins per 18 pounds of concentrate used. The average weights for the chicks used in this series with probable error determinations for the last weighing are given in Table 5.

TABLE 5.—*Third series—35 chicks per lot*

Lot No.	Protein Concentrate	Weights			Deaths
		Initial	28 days	56 days	
		Gms.	*Gms.*	*Gms.*	*No.*
941	Meat and bone meal	62	249	655 ±12	2
942	Half meat and bone meal plus half dried buttermilk	61	288	684 ±9	0
943	Three-fourths meat and bone meal plus one-fourth dried buttermilk	61	291	733 ±13	0
944	Half meat and bone meal plus half linseed oil meal	61	259	620 ±11	0
945	Half meat and bone meal plus half cottonseed meal	60	253	628 ±11	2
946	Half meat and bone meal plus half corn gluten meal	61	240	587 ±12	0

Reasoning from this experiment one can observe that dried buttermilk and meat proteins supplement one another more efficiently when combined on a basis of 75 per cent meat and 25 per cent milk than when combined on a 50 per cent meat and 50 per cent milk basis. Combinations of meat and the various plant protein concentrates were more efficient than the plant protein concentrates, but were not so efficiently used as the meat proteins.

In the fourth series of experiments several protein concentrates hitherto not included were used as well as several pure proteins and two combinations. Chart IV graphically presents the results of this series and Table 6 gives the weight data for the respective groups.



This series of experiments indicates that soybean meal justly deserves its good reputation as a high quality protein concentrate. A comparison of the curves for Lots 955, 956, and 961 shows that the concentrate made of half meat and bone meal protein and half soybean meal protein resulted in a slightly better growth rate than was observed in the meat and bone meal lot. The ratio of the difference in the average weight of these two lots to the probable error of the difference is, however, only 1:1.88, and cannot be considered highly significant.

TABLE 6.—*Fourth series—33 chicks per lot*

Lot No.	Protein Concentrate	Weights			Deaths
		Initial	28 days	56 days	
		Gms.	*Gms.*	*Gms.*	*No.*
955	Meat and bone meal	50	253	633 ±11	0
956	Soybean meal	53	253	625 ±10	0
957	Fish meal (Menhaden)	50	299	780 ±12	0
958	Casein	52	282	710 ±8	1
959	Gelatin	51	132	289 ±10	0
960	Half meat and bone meal plus half fish meal	50	274	673 ±10	1
961	Half meat and bone meal plus half soybean meal	52	255	665 ±13	0

The high biological value of fish meal is shown by comparing the growth curves for Lots 955 and 957. Fish meal proteins in this experiment showed a better biological value than casein, which is known to be quite complete in all the essential amino acids.

Gelatin has long been known to be an incomplete and inadequate protein. It lacks the following amino acids: tyrosine, tryptophane and the sulfur containing cystine. Birds and mammals differ physiologically in some fundamental respects, but they are apparently very similarly limited in their

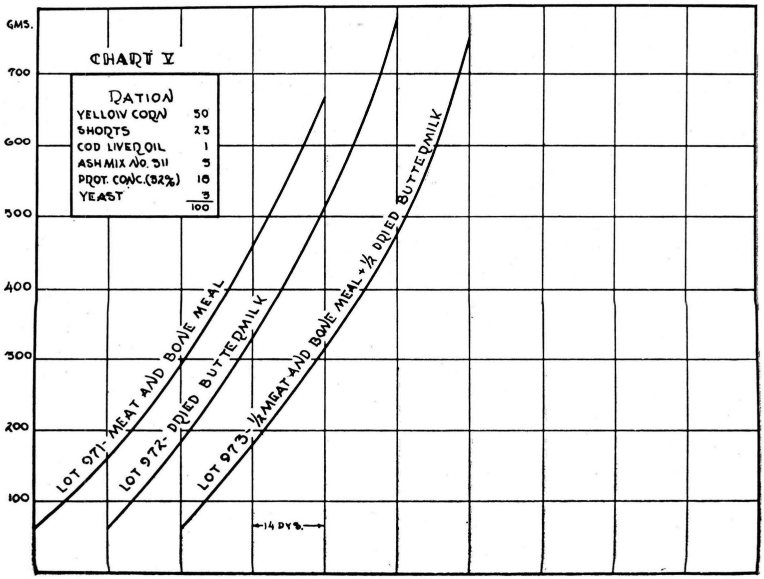


TABLE 7.—*Fifth series—66 chicks per lot*

Lot No.	Protein Concentrate	Weights			Deaths
		Initial	28 days	56 days	
		Gms.	*Gms.*	*Gms.*	*No.*
971	Meat and bone meal	68	291	677 ±9	3
972	Dried buttermilk	67	336	784 ±10	2
973	Half meat and bone meal plus half dried buttermilk	68	321	750 ±8	0

ability to utilize gelatin for the production of new body tissue.

For the fifth series of experiments the objective was a more accurate determination of the comparative biological value of meat and bone meal, dried buttermilk, and a half-and-half combination of these concentrates. Chart V represents the growth experience of 198 chicks divided into three equal lots and used for the experiment. Additional data are given in Table 7. A statistical study of the final weights of the chicks used (see Table 8) shows significant differences in the growth rates.

TABLE 8.—*Difference between mean weight of chicks at end of experiment on meat and bone meal and other protein concentrates as indicated*

Protein Concentrate	Difference, in grams	Ratio of difference to P. E. of difference
EXPERIMENT NO. 1 (*30 chicks per lot*)		
Dried buttermilk	21 ±28	0.7
Blood meal	127 ±19	6.7
Linseed oil meal	209 ±19	11.0
Cottonseed oil meal	135 ±23	5.9
Gluten meal	266 ±20	13.3
EXPERIMENT NO. 2 (*27 chicks per lot*)		
Dried buttermilk	19 ±26	0.7
Blood meal	291 ±26	11.2
Linseed oil meal	377 ±26	14.5
Cottonseed meal	260 ±26	10.0
Gluten meal	264 ±27	9.8
EXPERIMENT NO. 3 (*35 chicks per lot*)		
One-half meat and bone + one-half dried buttermilk	29 ±15	1.9
Three-fourths meat and bone + one-fourth dried buttermilk	78 ±18	4.3
One-half meat and bone + one-half linseed oil meal	35 ±16	2.2
One-half meat and bone + one-half cottonseed meal	27 ±16	1.7
One-half meat and bone + one-half gluten meal	68 ±17	4.0
EXPERIMENT NO. 4 (*33 chicks per lot*)		
Soybean meal	8 ±15	0.5
Fish meal	147 ±16	9.2
Casein	77 ±14	5.6
Gelatin	344 ±15	22.9
One-half meat and bone + one-half fish meal	40 ±15	2.7
One-half meat and bone + one-half soybean meal	32 ±17	1.9
EXPERIMENT NO. 5 (*66 chicks per lot*)		
Dried buttermilk	107 ±14	7.6
One-half meat and bone + one-half dried buttermilk	73 ±12	6.1

One is of course influenced in the choice of a ration for practical poultry production not only by the biological value, but also by the comparative cost per protein unit. The cost factor will vary from time to time, but the biological value of standard products used to supplement standard basal rations will remain constant.

EXPRESSING COMPARATIVE BIOLOGICAL VALUES

A precise evaluation of the nutritive value of our protein contributing concentrates is admittedly impossible at the present writing. The fairest interpretation can probably be made by using the letter system of indicating values, letting A A represent the highest quality, A the next grade, B B the next, etc. By this method of expressing relative values, the following rating is suggested for the concentrates used in these experiments:

Dried buttermilk	A A	Blood meal	B
Fish meal	A A	Cottonseed meal	B
Casein	A A	Linseed oil meal	C
Meat and bone meal	A	Corn gluten meal	C
Soybean meal	A	Gelatin	D

CONCLUSIONS

1. There is a marked difference in the nutritive value of the various protein-contributing concentrates when used to supplement a corn-wheat basal ration which has been made complete for known vitamin and mineral essentials.
2. There is a great difference in the biological value even of animal protein concentrates.
3. Soybean meal produced a better growth rate than any of the other plant concentrates used. Cottonseed meal proved to have a greater growth-promoting value than did linseed oil meal.
4. The supplementing values of protein concentrates, one to another, is not quite as evident as one would expect if the commonly stated theory of protein utilization is accepted without question.

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